Dynamic mechanochemistory of seismic slip - lubrication by super saturated fluids

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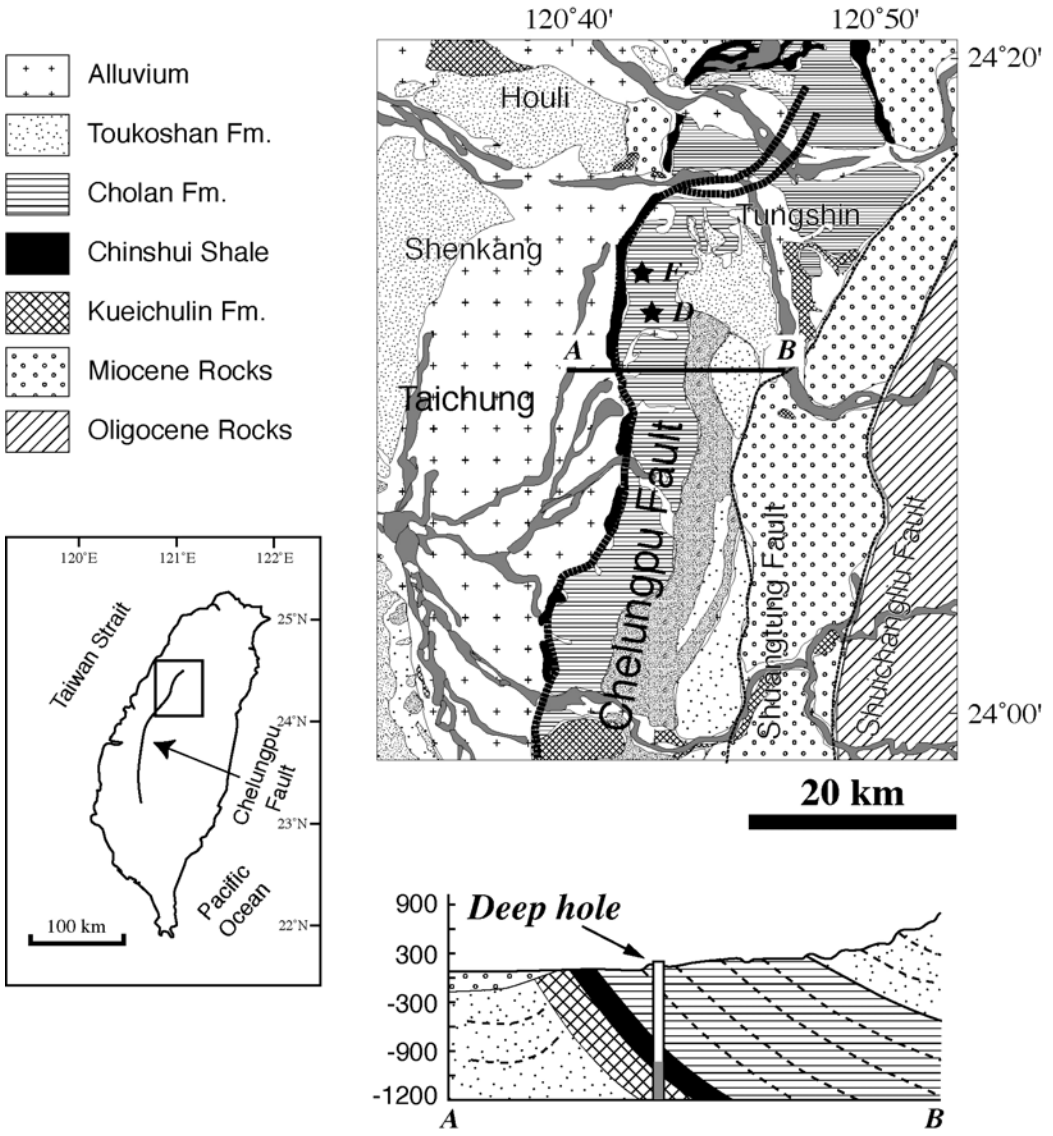
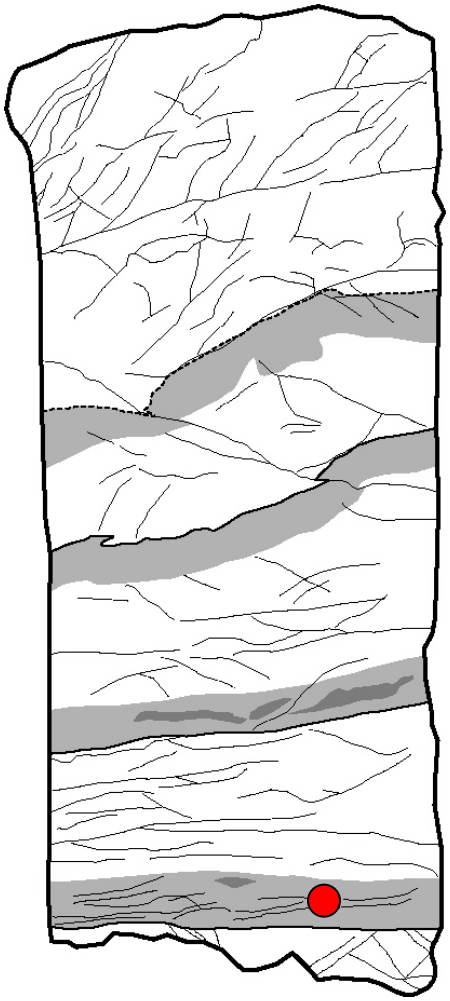
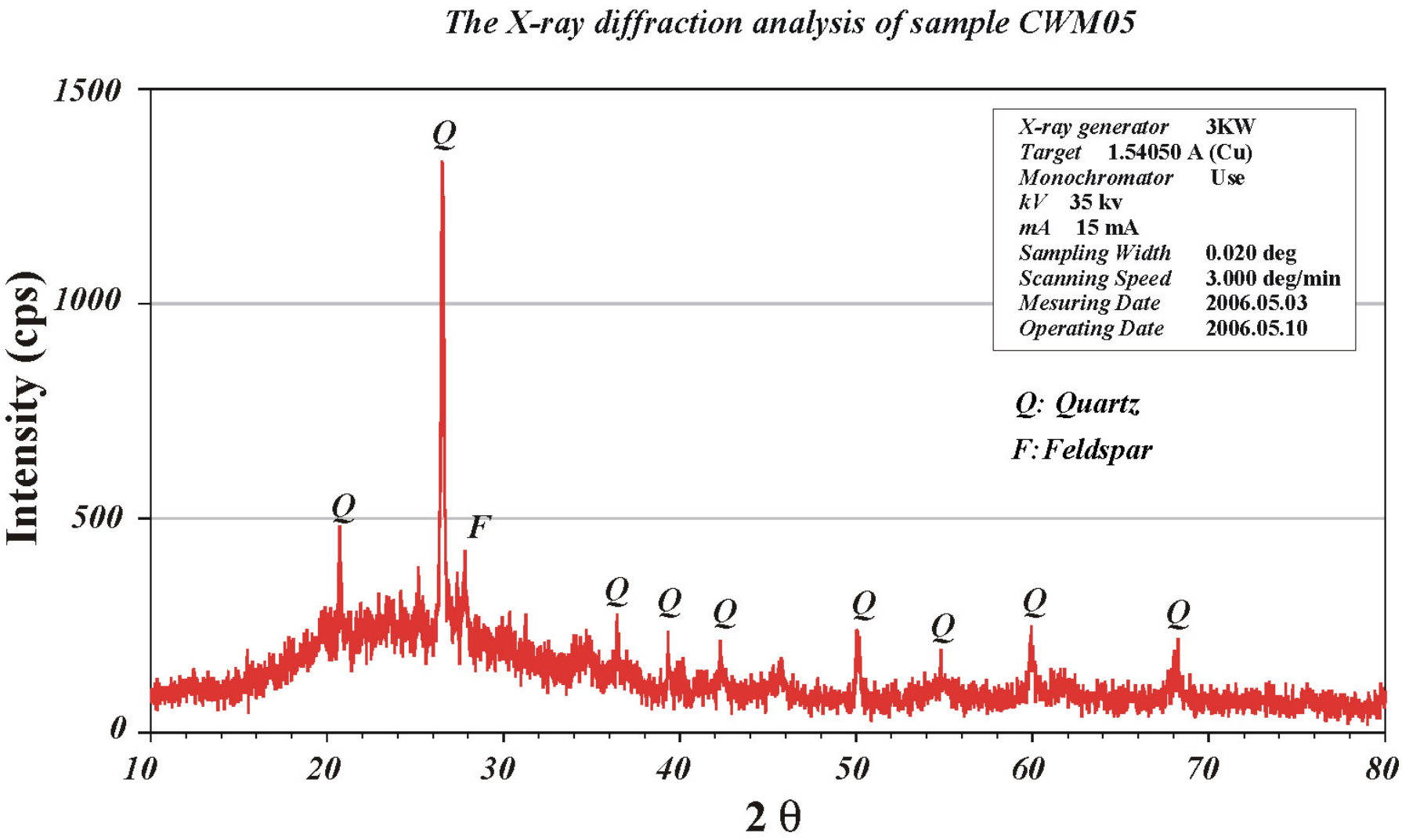
Geological map of drilling site

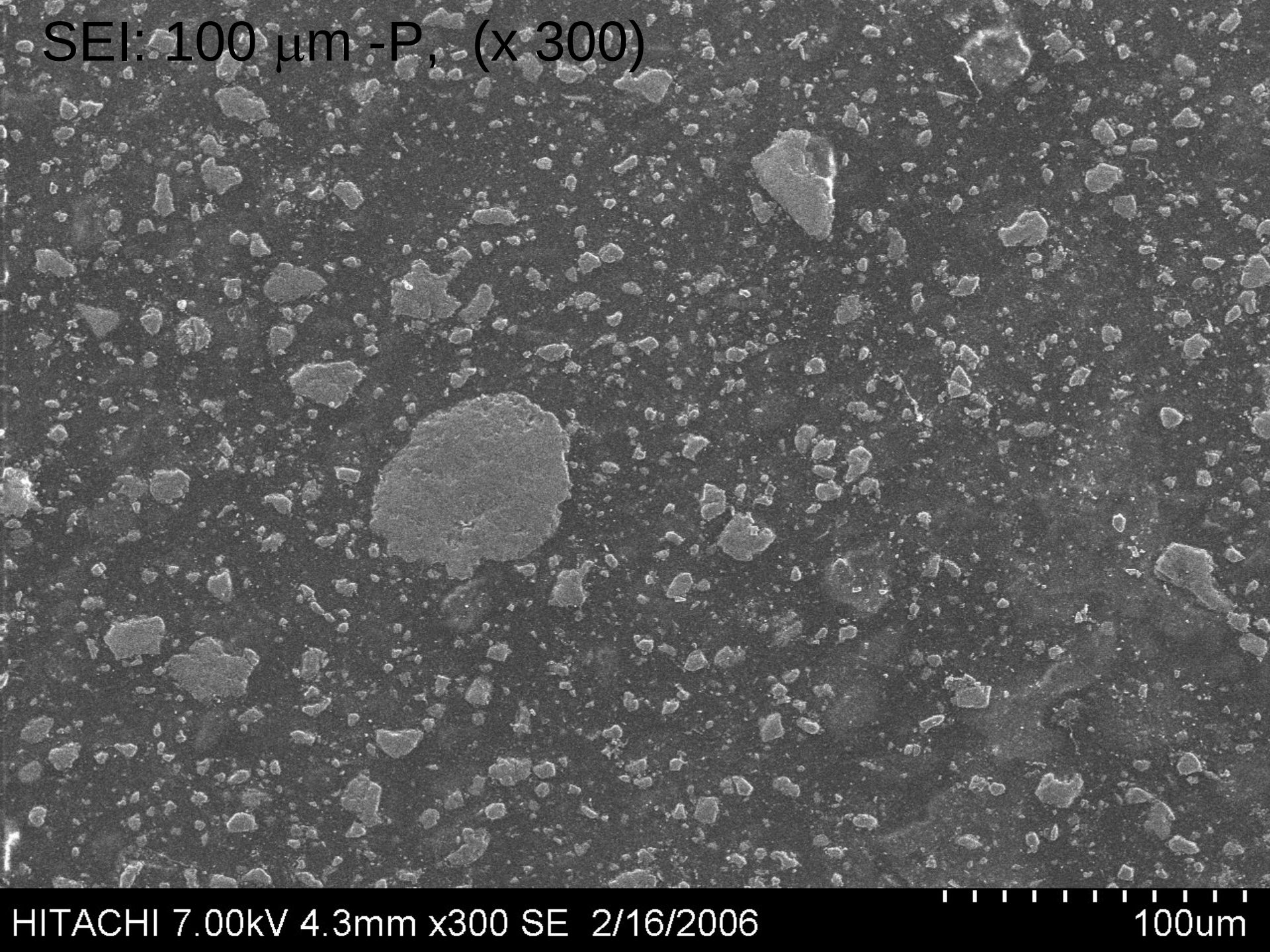


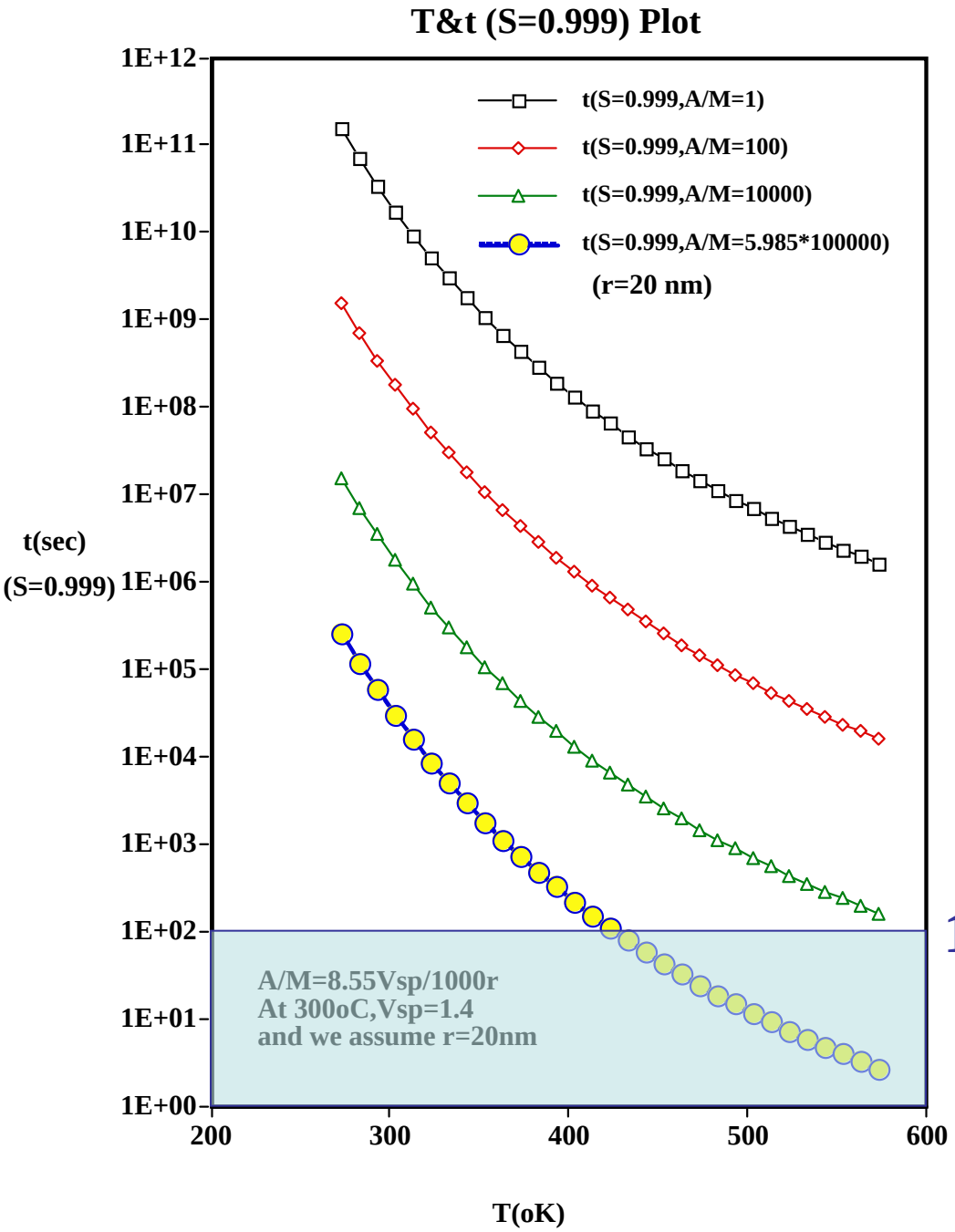
Polished Slab of 1138 m slip zone in hole C



XRD Results


The X-ray diffraction analysis of sample CWM05
Intensity (cps)
1500
1000
500
0
10
20
30
40
50
60
70
80
2 θ
Q
F
X-ray generator 3KW
Target 1.54050 A (Cu)
Monochromator Use
kV 35 kv
mA 15 mA
Sampling Width 0.020 deg
Scanning Speed 3.000 deg/min
Mesuring Date 2006.05.03
Operating Date 2006.05.10
Q: Quartz
F: Feldspar


SEI: 100 μm -P, (x 300)
HITACHI 7.00kV 4.3mm x300 SE 2/16/2006
100um



Size dependent dissolution of quartz into solution

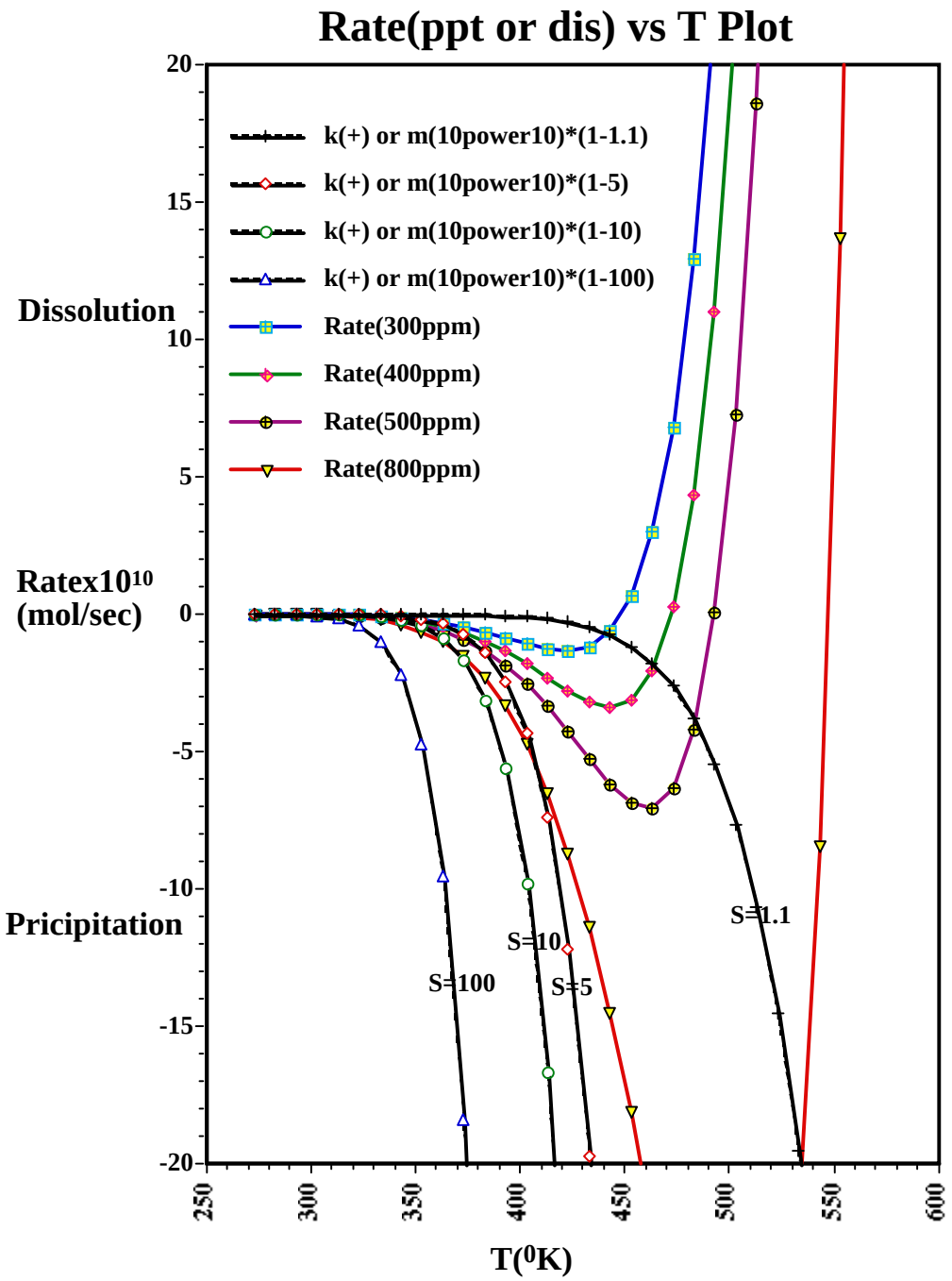
$$r_{H_4SiO_4} = \left(\frac{A}{M}\right)\left(\gamma_{H_4SiO_4}\right)\left(k_+ a_{SiO_2} a^2{}_{H_2O}\right)\left(1 - Q/K\right)$$

A: Interfacial Area
M: Relative mass of fluid
a: Activity
Q: Activity product
K: Equiliblium constant
γ : Activity coefficient
k_+:Dissolution rate constant

Rimstidt and Barnes (1980), GCA

10 s *Seismic slip duration*

Fluid becomes super-saturated and worked as lubricants



Rate change of precipitation of quartz from super-saturated fluid

$$r'_{H_4SiO_4} = dm_{H_4SiO_4}/dt = k'_+\left(1 - Q/K\right)$$

m; concentration
r'; rate of change of m with time
k'_+; apparent dissolution rate constant
Q: activity product
K: equiliblium constant

Rimstidt and Barnes (1980), GCA

Precipitation from super-saturated fluid occurs quickly to generate nano spherules.

Summary and discussion (1)

(1) Grains are observed under OM, SEM,and HR-TEM, from 1 nm to 100 um in grain diameter. Under SEM (SEI) observation, many of **fractured grains are enveloped by viscous thin film.**

(2) Minimum size of grains observed under HR-TEM is 3 nm. The grain size distribution for grains larger than 100 nm in diameter follows the fractal law and grain shape is highly irregular. Grains smaller than100 nm show that smaller the grains, more the spherical shapes and more equi-granular, indicating **grains smaller than 100 nm are no longer described by fractal distribution model**. We refer tentatively these grains as **“Nano spherules”**.

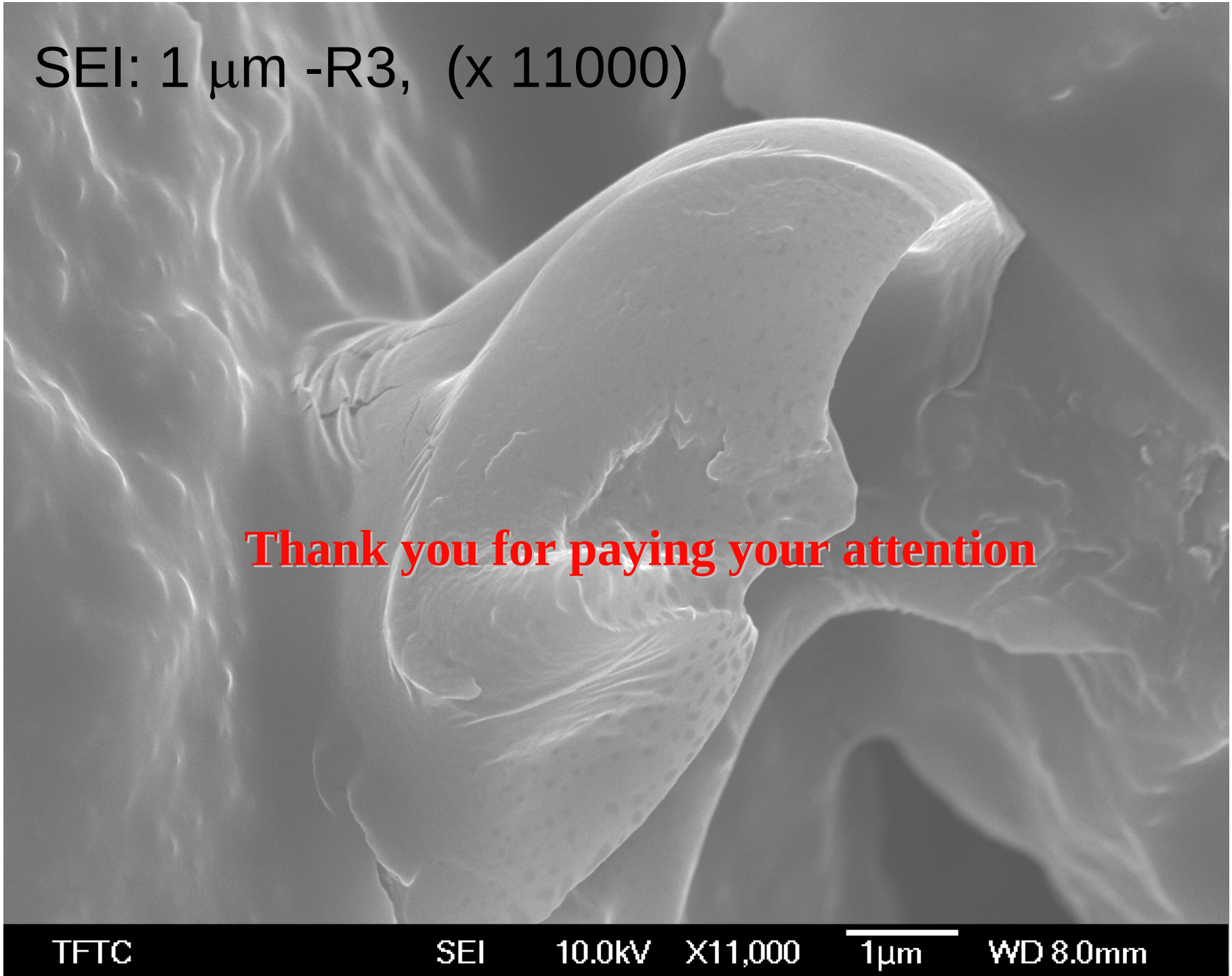
(3) Nano spherules are not generated just by fracturing, based on their shapes and grain size distributions. Considering the results of SEM observations, nano spherules would compose viscous materials enveloping larger fractured grains.

Summary and discussion (2)

(4) By SAD and EDX analysis under HR-TEM, **the nano spherules are mainly composed of crystallized quartz** associated with minor amounts of carbonates (siderite) and amorphous materials. The result corresponds well with that of XRD analysis. Mica clay minerals and feldspars, which are common in host mudstone rocks, are disappeared.

(5) By GTP calculations (Urata et al in submission), maximum temperature in the slip zone attains to 1000 degree C, Slightly lower the melting temperature of quartz. Also no clear evidence of melting has been found from slip zone (such as amigudules, dendritic crystals and microlites). Alternative explanation is that **nano spherules were generated through mechano-chemical process associated with co-seismic slip.**

(6) Dynamic shear strength drop are observed by rapid slip experiments (DiToro et al., 2004). These experiments reported that the products contain gelled materials. **Gels would be worked as lubricants to reduce the friction during dynamic slip. Also gels would be resources for precipitation of nano-spherules of quartz.** We show some kinetic examinations of quartz-fluid reaction next.


SEI: 1 μm -R3, (x 11000)
Thank you for paying your attention
TFTC
SEI
10.0kV
X11,000
1μm
WD 8.0mm